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BRIGHT SOIL UNITS ON MARS DETERMINED FROM ISM IMAGING SPECTROMETER DATA

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Introduction. The lithology of bright Martian soil provides evidence for chemical and physical processes that have modified the planet's surface. Data from the ISM imaging spectrometer [1], which observed much of the equatorial region at a spatial resolution of ~22 km, cover the NIR wavelength range critical to ascertaining the presence and abundance of Fe-containing phases, hydroxylated silicates, and H_2O in the bright soil. ISM data previously have revealed spatial variations in depth of the 3.0-μm H_2O absorption suggesting differences in water content [2,3], a weak absorption at 2.2 μm indicative of metal-OH in phyllosilicate [3], and variations in the 1-μm Fe absorption indicative of differences in Fe mineralogy [4]. This abstract summarizes first results of a systematic investigation of spectral heterogeneity in bright soils observed by ISM. At least seven "units" with distinctive properties were discriminated. Comparison of their spatial distributions with *Viking* data shows that they generally correspond with previously recognized morphologic, color, and thermal features. These correspondences and the units' spectral attributes provide evidence for lithologic differences between the soils in different geologic settings.

Analysis. We investigated 6 of the 9 data "windows" returned by ISM, covering Tharsis, Arabia, and Isidis. Bright soils in these areas contain examples of most variations in color, reflectance, and thermal inertia that have been recognized in *Viking* data [e.g. 5-8]. Calibration and removal of atmospheric absorptions were performed using previously described methods [2,9]. The data were reduced to a suite of "parameter" images that describe key sources of spectral variability. These include reflectance, strength of the narrow 2.2-μm absorption, depth of the 3.0-μm H_2O absorption, and NIR spectral slope. Spectral slope of Mars analog materials is affected by several variables. Particulate basaltic and ferric materials have flat spectral slopes, but negative spectral slopes occur when the ferric component coats or is intimately mixed with a dark substrate [10-12] or has an extremely fine particle size [13]. Atmospheric scattering may also cause negative spectral slopes in ISM data [2]. Spectral slope was measured as the difference between reflectances at 1.71 and 2.47 μm. If atmospheric scattering makes a nearly constant contribution to reflected light, then *variations* in spectral slope calculated in this way should be related to surface properties.

Preliminary soil groupings were identified using the parameter images, based on systematic, spatially coherent differences in spectral slope and depths of the 2.2- and 3.0-μm absorptions. Representative spectra of the groupings were extracted, and absorption features due to Fe in minerals were identified and analyzed. Where appropriate, the preliminary groupings were subdivided based on differences in these absorptions. Finally, spatial distributions of the resulting "units" were compared to surface morphology, visible color, and thermal properties evident in *Viking* data.

Results. Figure 1 illustrates variations in spectral slope and strengths of the 2.2-μm and 3.0-μm absorptions. Six preliminary "groupings" (Table 1) were identified based on systematic, spatially coherent differences. In a comparison of strengths of the 3.0-μm and 2.2-μm absorptions (Fig. 1a), the geographically largest grouping ("normal bright soil") exhibits a relatively weak 3.0-μm absorption and strong 2.2-μm absorption. This soil covers most "bright red" parts of Tharsis and Arabia. However in soils on Tharsis Montes, especially Ascraeus Mons, both absorptions are weaker. The remaining groupings have stronger 3.0-μm H_2O absorptions, and are loosely termed "hydrated bright soils" [3]. Parts of Lunae Planum and Arabia with "dark red" visible color and the interior of Candor Chasma have stronger 3.0-μm absorptions and weaker 2.2-μm absorptions than normal bright soil. Isidis is unique in having both a strong 3.0-μm absorption and a strong 2.2-μm absorption. Two further groupings are discerned by comparing spectral slope and strength of the 3.0-μm absorption (Fig. 1b). Soil in cratered highlands in Libya Montes is distinguished from normal bright soil by a more negative spectral slope. Soil in Candor Chasma is distinguished from hydrated "dark red" soil by both a negative spectral slope and a stronger 3.0-μm absorption.

Variations in the positions, shapes, and depths of Fe-related absorptions further define and in some cases subdivide these groupings (Table 1). Normal bright soil in Tharsis has a shallow ferric iron absorption centered near 0.85 μm, but normal bright soil in Arabia has a deeper absorption centered near 0.92 μm [4]. Soil at high elevations on Ascraeus Mons exhibits a distinctive ferric absorption centered near 0.88 μm [4], in addition to the differences described above. "Hydrated bright soils" also have Fe-related absorptions different from normal bright soil. These may contain ferric iron phases, glasses, or pyroxene, and are currently being investigated [cf. 4].

Discussion. The soil units generally exhibit spatial correlations with surface units derived by interpretation of surface morphology, *Viking* visible color, and thermal inertia measurements [5-8] (Table 1). These correlations corroborate the compositional heterogeneities of bright soil inferred from ISM data.

"Normal bright soils" correspond almost exactly with low thermal inertia regions interpreted as accumulations of "dust" by airfall [6-8]. The absorptions at ~0.9 and 2.2 μm indicate that the "dust" contains ferric minerals and poorly crystalline phyllosilicate [3,4]. The Fe absorption at 0.85 μm throughout the Tharsis region is indicative of hematite, but the absorption at 0.92 μm throughout Arabia indicates one or more different Fe phases [4]. This difference clearly implies that "dust" is not a single, globally homogeneous lithology, but rather that its lithology varies between regions. In addition, compared to the surrounding Tharsis plains, soil or "dust" at high elevations on Ascraeus Mons exhibits a more negative spectral slope, weaker 2.2-μm and 3.0-μm absorptions, and a ferric

absorption offset to longer wavelengths by ~0.03 µm. The offset in the ferric absorption is similar to that seen in the laboratory in extremely small grain sizes of hematite [14]. Finer-grained "dust" high on the volcanoes than in the surrounding plains may also explain the weaker 2.2-µm and 3.0-µm absorptions and the negative spectral slope.

"Hydrated bright soils" correspond to bright soils outside the low-inertia regions interpreted as airfall deposits. They exhibit greater spectral heterogeneity than "normal bright soil," as well as correlations with independently identified high thermal-inertia features and geologic units. As such, they may be representative of exposures of more indurated soil and/or high-albedo geologic deposits. For example, "dark red" plains in Lunae Planum and Arabia correspond to high thermal inertia surfaces previously interpreted as cemented duricrust [6,15]. Their strong 3.0-µm absorptions suggest enrichment in a water-bearing phase, perhaps hydrated salts acting as the duricrust's "cement."

The Isidis unit also corresponds with material having anomalously high thermal inertia [7,8], as well as with a thick surface deposit mapped by Grizaffi and Schultz [16]. The Isidis deposit's high inertia and strong 3.0-µm absorption would also be consistent with induration of soil by water-bearing cement, but it has a bright red color and strong 2.2-µm absorption which suggest a different compositon of cemented particulates than in "dark red" soils.

The unit in Candor Chasma corresponds with highly eroded layered deposits sculpted by eolian fluting [17]. This unit is distinctive from other bright soils, but it is surrounded by a ~100-km-wide "halo" transitional with normal bright soil (see Figure 1). This gradational contact may imply that eolian processes have transported debris from the layered deposits into surrounding plains, suggesting a discrete source region for some bright airfall deposits.

TABLE 1. Spectral Properties and Geologic Correlations of Bright Soil Units[1]

Unit	3.0-µm band	2.2-µm band	Spectral slope	Center of ferric absorption	Correlations with vis. color, thermal inertia, geology
"Normal Bright" (Tharsis)	Weak	Strong	Flat	0.85 µm	Bright red, low inertia
"Normal Bright" (Arabia)	Weak	Strong	Flat	0.91 µm	Bright red, low inertia
Tharsis Montes	Very weak	Moderate	Negative	0.88 µm	Dark red, low inertia, high-elevation flanks of volcanoes
Libya Montes	Weak-moderate	Strong	Negative		Bright red, heavily cratered highlands
"Hydrated bright soils"					
"Dark red" plains (E Lunae Planum, W Arabia)	Moderate	Moderate	Flat		Dark red, high inertia
Candor Chasma	V. strong	Weak	V. negative		Layered deposits
Isidis	Strong	Strong	Flat		Bright red, high inertia

[1] "Groupings" based on spectral slope and depths of the 2.2-µm and 3.0-µm absorptions are separated by solid lines.

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